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Contents

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REVIEWS AND ABSTRACTS

In this section of the N.A.A.S. Quarterly Review, it is intended to survey current research and experiment in agriculture, horticulture and the allied sciences applicable to the work of the National Agricultural Advisory Service. It will not be possible, of course, to cover more than a small part of this wide field in each issue.

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The Use of Hormones in Animal Nutrition

T. D. BURGESS* and G. E. LAMMING
University of Nottingham School of Agriculture

DURING THE PERIOD from 1920 to 1950, workers in animal nutrition were mainly interested in the fields of intermediary metabolism and vitamin research. Over the past few years a great deal of interest has developed in the use of hormones as stimulants, particularly to increase the rate of growth and fattening and to increase milk production. The use of hormones to improve growth rates in ruminants has received particular attention, and since 1948 a great deal of literature has appeared concerning studies using both natural and synthetic steroid hormones. The results obtained in these studies, particularly where stilboestrol (a synthetic "oestrogen") was used, have been most encouraging. Since most of these experiments were conducted in the United States, where the management of fattening animals is different from that in Great Britain, it does not necessarily follow that similar results would be obtained under British conditions.

One essential for the successful use of a hormone in the field of animal production is that there shall be a fairly wide tolerance to excessive levels of the hormone concerned. If the balance between sufficient stimulation and gross excess is narrow, then the use of such stimulants may lead to serious abuse (e.g., feeding thyroxine or thyroprotein to dairy cows). Where implantation can be used (e.g., stilboestrol implantation of poultry), the level of administration is fixed within fairly narrow limits. This removes the necessity of strict control of hormone-supplemented feed, which under normal farm conditions may be so difficult to achieve that its use cannot be recommended.

Implantation of Fattening Sheep

Reports concerning the use of hormones in lamb production are so numerous that space does not permit a detailed account of them here. The substances most commonly used have been the synthetic hormones diethylstilboestrol, hexoestrol and dienostrol and the natural hormone oestradiol. The use of progesterone in combination with these substances has also been investigated. The majority of the reports are from the United States and concern the use of stilboestrol mostly by subcutaneous implantation, although oral administration has also been tried.

The implantation of oestrogenic hormones in suckling lambs has produced a varied response. Jordan [23 and 27] was unable to demonstrate an increase in average daily gain when suckling lambs from

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*Canadian N.R.C. Scholar on leave of absence from Ontario Agricultural College.

24 to 58 lb were implanted with either 12 or 24 mg stilboestrol. Wilkinson [50] reports similar results using a combination of progesterone and oestradiol. Averill [6] found no advantage using varying levels of hexoestrol implantation. On the other hand, Perry [40] obtained significant increases of gain using a 12 or 24 mg implant of stilboestrol in suckling lambs of 45 lb, and Clegg [14] found in a large-scale field trial that implants of from 12 to 36 mg were effective in increasing rates of gain, regardless of age at the time of treatment. Stephens [44] found that a 15 mg implant of stilboestrol was effective in increasing rates of gain in lambs running with their dams on pasture.

In an experiment conducted at the University of Nottingham School of Agriculture during 1955 and 1956, 12 mg of stilboestrol was implanted subcutaneously in the ears of suckling male lambs of 40 lb live weight. It failed to produce any significant increase in rate of gain. These lambs were already making approximately 0.75 lb liveweight gain per day which may have precluded a further increase.

The variability in the results obtained in suckling lambs indicates that lambs of this age will not respond uniformly to treatment. It may be that the oestrogenic substances known to be present in spring grass affect the response to hormone implantation, or that the age and maturity of the lambs is involved. In any case, reports of experiments using oestrogenic hormones in older, heavier lambs indicate that in these animals a more uniform response may be expected.

Older fattening lambs have usually been implanted at about 60 lb live weight or heavier, and where stilboestrol has been used the level of implantation has ranged from 6 to 36 mg per lamb, with the following results:

Number of Trials	Weight of Implant	Average Increase in Rate of Gain
	mg	*lb*
4	6	0.09
14	12	0.41
1	15	0.113
4	24	0.12
1	30	0.077

From these results there appears to be little advantage to be gained in using implants above 12 mg stilboestrol per lamb.

Combinations of progesterone and oestrogens have also been used. Galloway found that an implant of 250 mg progesterone and 25 mg stilboestrol gave an increase in daily gain of 0.11 lb. Jordan [26] found an increase of 0.05 lb in daily gain using a combination of 6 mg stilboestrol and 50 mg progesterone. Luther and Henneman used an implant of 10 mg oestradiol and 250 mg progesterone and obtained increases in daily gains of 0.15 lb and 27 per cent respectively. Henneman [22] compared combinations of 10 mg oestradiol and 250 mg progesterone and 10 mg oestradiol and 100 mg progesterone and

obtained 35.5 per cent and 42.5 per cent increases in rates of gain respectively. Andrews [4] was unable to show any advantage using dienestrol implants, while Means [36] found that in a high viscosity base dienestrol was effective in promoting gains but not where a low viscosity base was used. Gill *et al.* [19], in a recent report from the Rowett Research Institute, found that a 15 mg implant of hexoestrol was effective in producing significant increases in gains where the daily rate of gain was reasonably high, but was not effective in lambs where the level of gain was low. In work done here in the past year, a 12 mg implant of stilboestrol has significantly increased the rate of gain of lambs fattening during the winter by an average of 33 per cent, and the greatest increase was obtained in the group of lambs making the slowest gain.

Oral administration of oestrogenic substances has not produced the uniform benefits found for implantation. Jordan [29 and 30] found no advantage from the feeding of levels of 0.1 to 2.0 mg stilboestrol per head per day, whereas Hale [20 and 21] obtained significant increases in rate of gain where stilboestrol was fed at levels of 1.5, 2.0 and 3.0 micrograms per lb of the ration and at 2 mg per head per day. Light [34] found that levels of 0.5, 1.0 and 2.0 mg stilboestrol per head per day resulted in significant increases in rate of gain.

Effect of Sex Hormone-Treatment on Carcass Quality

Stilboestrol treatment has been reported to reduce carcass grade in those trials where carcass quality has been assessed on the basis of Federal grades. In the few trials where detailed carcass analyses have been carried out there have been few significant differences found in the carcasses. It has been fairly uniformly reported that stilboestrol treatment does cause a decrease in the fat covering of the carcass, and there are conflicting reports as to its effect on the moisture content of the meat.

Other effects of oestrogenic treatment have been the development of the mammary glands, enlargement of the secondary sex glands, and a prolapse of the rectum or vagina which, according to Jordan has caused serious death losses in certain groups of lambs. In the field trials conducted by Gill *et al.* [19], no case of prolapse was found in a total of 524 lambs used, and in our own work one case was found from a total of 253 male lambs used.

The Use of Androgens in Sheep

The use of androgens has received less attention. Andrews [2] obtained increases in rates of gain of 0.08 and 0.06 lb with implants of 10 and 20 mg testosterone. Although Means [36] found that an implant of 30 mg testosterone gave an increase of 0.09 lb daily, Pope [42] and Henneman found no significant increase in gain, nor did O'Mary [38], who gave the testosterone by weekly intramuscular injections of 20 mg.

However, Taylor [45] fed levels of 2.41 mg and 12.07 mg testosterone per lb of the ration and obtained a 16 per cent increase in rate of gain in lambs. He also reports that fortnightly injections of 3.3 mg testosterone per 100 lb body weight resulted in a 34 per cent increase in daily gain.

Use of Steroid Hormones in Cattle

By Implantation. Most of the work using sex hormones in cattle deals with trials conducted in the United States under feed-lot conditions. The levels of stilboestrol given by implantation have ranged up to 120 mg per head. Using a level of 36 mg, O'Mary [39] obtained an increase in daily gain of 0.4 lb. In two trials where a 42 mg implant was used the average daily rate of gain was increased by 0.32 lb, and in nine trials in which a 60 mg implant was used, the treatment produced an average increase in daily rate of gain of 0.49 lb [3, 5, 14, 16 and 32]. In four trials where a 120 mg implant was used, it produced an average increase of 0.48 lb in daily gain [3, 4 and 16]. Aitken and Critchon [1] at the Rowett Research Institute used a 120 mg implant of hexoestrol in one animal of identical twin steers and obtained a 0.56 lb increase in daily gain. In field trials conducted here with yard-fed steers, an increase in gain of 0.79 lb daily was obtained with a 60 mg implant of stilboestrol and an increase of 0.50 lb with a 36 mg implant of stilboestrol.

With cattle there appears to be little advantage in exceeding 60 mg by implantation and with animals on pasture lower levels appear desirable. In a trial during the summer of 1956, a group of steers implanted with 36 mg stilboestrol made 15½ per cent extra growth rate (2.8 lb per day average gain) compared to other non-treated steers which were gaining at approximately 2.4 lb per day.

The effects of oestrogen implants on the carcass are similar to those reported for lambs. In general, a lack of fat covering has been noted with a consequent decline in Federal grades. Side effects have included a depression of the loin, elevation of the tailhead and enlargement of the teats.

By Feeding. In attempts to offset the deleterious side effects encountered with stilboestrol implantation, attention has been given to oral administration. The most common level has been 10 mg stilboestrol per head per day. A summary of the results of a large number of trials using this level is given in the following table.

There is some disagreement as to whether the feeding of stilboestrol reduces the deleterious side effects found with implantation. Andrews observed a similar effect on the tailhead with both oral administration and implantation, whereas Burroughs and co-workers state that oral administration eliminates these undesirable effects.

A trial was conducted here during the 1955-56 winter in which 10 mg stilboestrol was given to one animal of dizygotic twin steers

maintained on equal food intake. This treatment resulted in an increase of 19 per cent in the rate of gain and a reduction of 13 per cent in the feed required to produce each pound of gain. Differences in dressing percentage and carcass quality were insignificant.

Summary of Feeding Diethylstilboestrol to Cattle in the United States*

Treatment	None	10 mg/head/day
HIGH ROUGHAGE RATIONS		
Cattle over 600 *lb* (7 *trials*)		
Average Daily Gain lb	1.58	1.84
% Feed Saved		17
Dressing Percentage	58.8	59.5
Cattle under 600 *lb* (3 *trials*)		
Average Daily Gain lb	1.75	1.82
% Feed Saved		3
Dressing Percentage	—	—
FATTENING RATIONS		
Cattle over 600 *lb* (12 *trials*)		
Average Daily Gain lb	2.09	2.43
% Feed Saved		13
Dressing Percentage	60.5	60.4
Cattle under 600 *lb* (3 *trials*)		
Average Daily Gain lb	2.17	2.44
% Feed Saved		10
Dressing Percentage	61.5	62.0

The Use of Androgens in Cattle

As in lambs, the use of androgens has received relatively little attention, and the results reported are variable. Perry [41] found a decrease in rate of gain with testosterone administration. Andrews [3 and 5], reported a slight increase in rate of gain in one trial and a decrease in another with testosterone implantation. Dinnusson [17] obtained a slight increase with testosterone implantation, and Luther found that a 300 mg implant of testosterone increased rates of gain. Burris and Bogart [13] report that weekly injections of 1 mg testosterone per kg body weight resulted in an increase in daily gain amounting to 0.40 lb. The adverse effects on carcass quality that have been reported for stilboestrol have not been noted when testosterone was used. A feeding trial conducted here where one member of dizygotic twins on equal feed intake received 5.0 mg testosterone per lb concentrates in the ration produced an increase of 19 per cent in rate of gain, and a reduction of 20 per cent in feed required to produce a lb of gain.

*Abstracted from Feeding Diethylstilboestrol to Beef Cattle. Eli Lilly & Company.

Assays for residual hormone in the meat of animals treated with oestrogens have indicated that if any hormone residues are present they are at a very low level and unlikely to be of importance as far as human consumption of the meat is concerned.

Metabolism and digestibility trials indicate that an increased digestibility is not the answer to the increased gain and feed efficiency found with stilboestrol administration. It would appear that the increase in feed efficiency is achieved after the food nutrients have been absorbed, and although the mechanism of its action is not known, it is likely to be under endocrine control. When we know more about the mechanism by which the extra growth is obtained in ruminants, it will make much easier the wider practical application of this relatively new advance in animal production.

The Use of Steroid Hormones in Poultry and Pigs

The chemical "caponization" of table poultry has become an integral part of poultry production. Both stilboestrol and hexoestrol are used and it is known that they cause pseudo-castration which increases fat deposition and produces a better finish to the carcass. It has been shown that the residual hormone present in the flesh is negligible and large amounts of chicken liver would have to be consumed before it became dangerous to humans. However, when neck offal containing pellet residues was fed to mink they failed to breed. It should be noted, however, that the effect of implantation in poultry is quite different from that in ruminants, for low level administration to ruminants results in a decrease in fat deposition. The level of administration to poultry is 10 to 40 times higher than to ruminants when compared with their respective body weights. While in final analysis the primary effect of implantation may be on the anterior pituitary gland, the final effects on the carcass are the opposite, for in poultry true structural growth does not occur.

Reports of feeding or implanting steroid hormones in swine are not encouraging and present conflicting results. Braude *et al.* [4] reported that feeding iodinated casein and stilboestrol to pigs improved rate of gain and feed utilization. Many authors have reported opposite results where stilboestrol has been the only additive used, and most reports contain references to excessive sexual activity especially among females. In most experiments, however, higher levels of hormone have been used than those found to be optimal for ruminants. It appears necessary to test the effect of feeding or implanting stilboestrol at much lower levels before a final decision may be given that such a procedure could be recommended for farm practice.

Use of Hormones Affecting the Thyroid

It has long been known that hypothyroidism or thyroidectomy depresses the growth rate of young animals and milk yield in the lactating adult.

The commercial production of iodinated casein in a cheap form made it possible to use it on a farm scale to study the effect of a small increase in metabolic rate on the growth of young animals and on milk production, particularly in cows in declining lactation. More recently, the production of relatively inexpensive L-thyroxine has made its commercial use possible. Similarly, the use of synthetic thiourea and thiouracil to depress metabolic activity has led to experiments testing the effect of hypothyroidism in farm animals, particularly its effect on the rate of gain of the fattening animal.

We now know that the balance between mild hyperthyroidism and excessive stimulation is too narrow for thyroprotein or thyroxine to be used successfully for most farm animals. Blaxter and co-workers [9] in England and workers in the United States conducted extensive trials in efforts to increase milk production from cows in declining lactation [c.f. Thomas, 46]. An increase in milk production of up to 60 per cent was obtained, depending on the animal, stage of lactation and the level of feeding. An increase of up to 0.3 per cent in fat test was achieved with no effect on s.n.f. However, it soon became obvious that extra nutrients were required to sustain body weight and the extra yield, at a level which resulted in no increase in the overall efficiency of milk production. In most herds similar increases in yield might be expected by giving extra feed without the danger of incurring excessive thyroid stimulation. Experiments where thyroprotein was fed for several lactations suggested that the thyroprotein-fed animals did not maintain their level of production over succeeding lactations [46].

Reports of increases in growth rate and feed efficiency in pigs have been given by Braude *et al.* [11], who used thyroprotein (500 mg per day) alone or in combination with either stilboestrol or antibiotics.

With thiourea it was observed that its administration to growing pigs depressed growth rate, and while it appeared to improve food conversion rate when fed to fattening pigs, it was only possible to feed it for a short time. Other investigators have studied the effects of both thiourea and thyroxine on growing poultry and hens in production and found no benefits sufficient to warrant their use on a commercial scale.

Use of Hormones in Animal Production

From the literature reviewed it would appear that there is no great immediate application for thyroid-depressing drugs or thyroprotein in animal production, for the hazards of their use outweigh any possible advantages. There appears to be a definite application for treatment with steroid hormones of the fattening ruminant. In sheep production, treatment of fattening lambs, particularly during the autumn and winter, offers a possibility of obtaining more efficient liveweight gains, and while the treatment does appear to reduce the amount of fat in the carcass, this decrease is not inconsistent with present demand.

Further investigations are required on the level and time of implant to achieve a finished carcass at suitable weights. The cost of implantation in sheep at 12 mg per head is approximately 1d., and from 50 to 80 sheep can be treated per hour under ideal conditions.

With cattle fed in yards, there appears to be a place for either oral administration up to 10 mg stilboestrol per day or implantation at levels up to 60 mg. Implantation appears preferable for cattle at pasture providing a cattle crush is available. The cost of stilboestrol for feeding is approximately 1d. per day and the cost of hormone for implantation is approximately 3d. to 6d. per head. The decrease in carcass quality in cattle, especially at the lower levels of administration, appears insufficient to cause concern. While some reports favour the use of androgens in sheep and cattle, further work is necessary before their commercial use can be recommended.

These treatments cause an increase in food efficiency, concomitant with the increased rate of gain. Present indications are that both yard-fed and pasture-fattened steers can reach market weight at an earlier age using this treatment, provided the level of feeding is adequate. As far as can be determined from the limited reports that are available, where low levels are fed to breeding stock there appears to be no detrimental effects on their later breeding performance.

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Interpreting the Results of Complicated Field Trials

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ALTHOUGH THE PRINCIPLES governing complex experimental design have been understood for over twenty years, and such experiments have long been the practice at research stations, only recently has their wider field use become at all general. The increasing complexity of modern field trials may prompt some regret because of the more intricate field work involved and the difficulties of interpretation, but the inescapable need to investigate more detailed and more complicated problems demands these methods of greater precision. The days have gone when results destined to become world-famous could be obtained from single non-replicated trials, such as those at Broadbalk, Rothamsted or Tree Field at Cockle Park. There is no need for the field worker to become a fully-fledged statistician, but without some understanding of the principles of statistics he cannot make the best and fullest use of his trials, and he may easily confuse himself, and others, by deducing erroneous conclusions from their apparent results.

In a previous article [1], the writer discussed some of the difficulties which could arise in the interpretation of the results from field trials of comparatively simple design: in this continuation he hopes to provide some help in relation to the more elaborate experiment layouts which are being increasingly used.

While these notes are largely concerned with the use of standard errors in determining whether the effect of a treatment is significant, it must be remembered that one of the main uses of the standard error is in fact to show whether a particular trial is sufficiently precise to be worth detailed examination.

Before studying the details of any trial, one must be satisfied that, no matter how simple or complex, it is reliable. Its results must apply to local conditions and to be of value they must be both capable of practical application and likely to be profitable in farm practice.

It is not proposed to recapitulate the previous discussion on these points, but merely to stress their fundamental importance; neither is it intended to repeat any of the explanation of statistical points in the earlier article, to which reference should be made.

Randomized Block Experiments with Many Treatments

Experiments of randomized block design are often carried out with as many as sixteen treatments. Although the number of replicates is then usually less than in a trial with only four to six treatments, the trial is still capable of giving accurate results.

There are many problems which cannot be adequately investigated unless a large number of treatments can be used. For example, a trial on the use of nitrogenous fertilizers on cereals will almost certainly include nitrogen at several rates, and, perhaps, applications of nitrogen at two or more dates. The experimenter may also wish to study at the same time comparisons between two fertilizers as sources of nitrogen, or between single applications and the same quantity applied in two or more doses.

An example of the results of a recent trial on the nitrogenous manuring of winter wheat is given in Table 1. These results, like all in this paper, are quoted as numerical examples and not as results from which advisory conclusions should be drawn. This trial included eleven treatments replicated four times.

Table 1
Yields of Cappelle Wheat (cwt/acre grain at 85% dry matter)

No Nitrogen	Fertilizer Used	Fertilizer cwt/acre Applied March 2	4	6	Applied May 2	4	6	3 Mar. + 3 May	Sig. Diff.	S.E. per treatment mean
		cwt/acre			*cwt/acre*			*cwt/acre*		
41.3	Sulphate of ammonia	51.1	55.6	56.5	50.1	51.5	52.9	59.5	4.48	1.55
	"Nitro-Chalk"	—	—	—	49.5	52.2	53.7	—		

S.E. per plot = 3.10 cwt/acre or 5.9 per cent.

The effect of nitrogen was clearly significant; all the plots receiving nitrogen have out-yielded the control by at least 8 cwt/acre, whereas a response of only $4\frac{1}{2}$ cwt would have been significant. The experimenter in this trial was, however, less concerned with confirming that nitrogen affected the yield of wheat than in studying the most economic way to apply it.

Considering firstly the time of application of sulphate of ammonia, it will be seen that at each level of fertilizer the yields from March application exceeded, but not by a significant amount, the corresponding yield produced by May application. One can, however, carry out a significance test to compare the yields produced by March and May applications. These average yields were:

$$\frac{51.1+55.6+56.5}{3} \text{ or } 54.4 \text{ and } \frac{50.1+51.5+52.9}{3} \text{ or } 51.5.$$

Each of these means was an average of twelve plot yields (three rates each replicated four times); the standard error* of each mean is:

$$\frac{3.10}{\sqrt{12}}=\frac{3.10}{3.46}=0.90$$

and the significant difference between them (3×0.9) is 2.7. Since the

actual difference was 54.4 - 51.5=2.9, it is just significant by this more precise test. The experimenter can, therefore, feel more confident that the slight advantage of March application was a genuine effect in this trial. Of course, since weather conditions affect nitrogen responses, no conclusion can be drawn from one trial, which would have to be repeated at several centres over a number of seasons before one could feel confident that such a result was of general applicability.

A similar test could be applied to the comparison between the two fertilizers applied in May, but the differences here are so small, inconsistent, and in practice, unimportant, that their statistical examination is unlikely to be worth while.

The application of 6 cwt of sulphate of ammonia at each date gave a slightly heavier yield of grain than the application of 4 cwt. However, when the 6 cwt was divided into two dressings of 3 cwt each, the yield was much heavier than that obtained from a single dressing of 6 cwt at either date. The average of the two undivided dressings was:

$$\frac{56.5+52.9}{2}=54.7 \text{ cwt}$$

and the difference between this and the yield of the divided dressing was 4.8 cwt (59.5 - 54.7). Although this difference exceeds the significant difference shown in Table 1, one cannot use this figure (which is derived from the S.E. of a single treatment mean) for a comparison involving the average of several such means.

The standard error* of this difference (4.8 cwt) is:

$$3.10\sqrt{\frac{1}{8}+\frac{1}{4}}=3.10\sqrt{\frac{3}{8}}=\frac{3.10\times1.73}{2.83}=1.90.$$

Since this is the standard error of a *difference*, the difference will be significant if it exceeds *twice* its standard error. Since 4.8 exceeds $2\times1.9=3.8$, the extra yield obtained here by dividing the nitrogen was a genuine effect.

Trials such as this are difficult to interpret unless there is some such grouping of the treatments: care should of course be taken only to group together treatments which are actually related. The "Nitro-Chalk" results, for example, can be compared only with the yields from sulphate of ammonia applied in May; they must not be included with the latter in a comparison between March and May applications of nitrogen. An experimenter reporting his results would normally

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*Where S=the standard error per plot (in units, not as a percentage)

S.E. of a mean of n plots$=\frac{S}{\sqrt{n}}$

S.E. of a difference of two means of n_1 and n_2 plots respectively$=S\sqrt{\frac{1}{n_1}+\frac{1}{n_2}}$

Where $n_1=n_2$ this becomes $S\sqrt{\frac{2}{n}}=\sqrt{2}\times\frac{S}{\sqrt{n}}$ or $2\times$ S.E. of a mean of n plots.

present the mean yields (and possibly their standard errors) which for the purposes of this example have been calculated.

To the adviser presented with tables of such complexity that he cannot "see the wood for the trees", the use of some graphic method or other may be of help, but such methods are seldom of value in conveying results to farmers.

Factorial Trials

It is now usual to superimpose manurial (usually nitrogen) treatments on cereal variety trials. This technique not only tests whether the individual varieties respond differently to nitrogen but gives much more information on their field characters, such as resistance to lodging, and possibly, their liability to certain diseases.

These trials may be carried out in one of two ways: the experimenter may either include all varieties at each level of manuring in every replicate (as in the example in Table 2), or he may use a design where several adjacent plots ("sub-plots" e.g., of different varieties) all receive a common treatment ("main plot" e.g., of fertilizer).

Some confusion may arise over the terminology of these designs. In NAAS/NIAB cereal trials, the main plot receiving a particular quantity of nitrogenous fertilizer is one complete block of six or more variety plots. It is then usual to speak of the main plot treatment being "applied over blocks" or, since its effect will be identified or confounded* with the block differences, "confounded with blocks". This procedure is essential in these trials, where it would not be practicable to provide, say, the twenty-one plots in each block needed to accommodate three fertilizer levels on each of seven varieties.

There is, however, no need for the main plots to be identical with the blocks; an experimenter can arrange his main plot to cover two, three, or more sub-plots as required. It is usual to restrict the term "split-plot experiment" to trials where the main plots are not complete blocks.

These methods may be forced on the experimenter for several reasons. It may be impossible to apply some types of treatment to very small areas of land; for example, commercial irrigation equipment cannot water small plots, and the preparation of seedbeds by farm implements in sowing-date experiments necessitates fairly large areas to work down at each date. In long-term experiments, such as those on perennial crops, the use of split-plots offers the experimenter a method of adding treatments to an existing trial to investigate subsidiary problems which may arise after the trial has been laid down.

Where complete randomization is possible, all the treatments are compared equally precisely, but a split-plot design, or one where

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*"To confound" is used statistically in the sense of "to fail to distinguish, to mingle so as to make the parts indistinguishable". The alternative dictionary definitions "to confuse, to perplex", however apt, are not recognized by statisticians.

treatments are applied to blocks, compares some treatments more precisely than others. Treatments applied to the larger main plots will usually be more affected by soil variation than those applied to the smaller sub-plots, and in practice may be inadequately replicated. Only very large differences, therefore, can attain significance. Treatments applied to the individual sub-plots will be more precisely compared, and their interaction with the main plot treatments will also be precisely determined. This may not matter if the main plot treatment is one in which the experimenter is not particularly interested.

COMPLETE RANDOMIZATION

An example of the results of this type of trial is given in Table 2. This shows the behaviour of two varieties of wheat each receiving four levels of nitrogenous manuring. The eight treatments (two varieties × four rates) were completely randomized and replicated four times, giving thirty-two plots in all.

Table 2

Grain Yields cwt/acre (corrected to 85 per cent dry matter)

Varieties	"Nitro-Chalk" (cwt/acre)				Mean
	0	$1\frac{1}{2}$	3	$4\frac{1}{2}$	
	(±0.73)				(±0.36)
Scandia	26.0	27.4	28.5	27.3	27.3
Hybrid 46	29.9	35.8	40.3	40.9	36.7
Mean (±0.51)	27.9	31.6	34.4	34.1	32.0

Standard error per plot : ±1.45 cwt/acre or 4.53 per cent.

It will be noted that this table contains three standard errors in addition to the standard error per plot. 0.36 is the S.E. of the mean yields of the two varieties (averaging all nitrogen levels); 0.51 is the S.E. of the mean yields of the nitrogen treatments (averaging both varieties) and 0.73 is the S.E. for comparing the eight individual yields in the "body of the table" and for testing interactions. Each of these S.E.s has been calculated from the figure of 1.45 cwt/acre by the methods outlined in the footnote on page 12. These calculations will not be repeated in detail, but the reader is advised to check the working.

Considering firstly the two main effects, variety and nitrogen response; since the difference between the mean yields of Hybrid 46 and Scandia (36.7 – 27.3=9.4 cwt) exceeds 3×0.36, Hybrid 46 has significantly out-yielded Scandia. Similarly, since both 3.7 (31.6 – 27.9) and 2.8 (34.4 – 31.6) exceed 1.53 (3×0.51), the effects of each of the first two increments of nitrogen have been significant.

In this experiment Hybrid 46 was more responsive than Scandia to

increased manuring. To test whether this greater response was a genuine effect or not, one must calculate the interaction between variety and manuring and test whether or not it is significant.

The interaction may be calculated from the body of the table directly:

$$\text{Interaction} = \frac{40.9+26.0}{2} - \frac{27.3+29.9}{2}$$
$$= \frac{66.9-57.2}{2}$$
$$= +\frac{9.7}{2} = +4.85$$

This interaction, since it exceeds three times its standard error (0.73), is clearly significant, proving that Hybrid 46 made better use of the nitrogen applied than did Scandia. To interpret this interaction, one must have access to the field records, since such an effect might arise through Scandia, a weaker-strawed variety, becoming lodged. In this trial there was very little lodging; except where $4\frac{1}{2}$ cwt "Nitro-Chalk" per acre was given to Scandia, it was negligible. Since the increased response of Hybrid 46 can be discerned (and is actually significant) even at the $1\frac{1}{2}$ cwt level, where no lodging occurred, one can conclude that this was a true varietal response in this trial and not a reflection of straw character.

MANURING APPLIED TO BLOCKS

Complete randomization in this way is usually only practicable where there are twelve or less treatment combinations. If three levels of nitrogen are given, the number of varieties, therefore, cannot exceed four. Most variety trials have many more varieties than this, and complete randomization cannot be adopted.

Table 3 gives an example of the results of a variety trial including nitrogenous manuring which was one of the NAAS/NIAB series commenced in 1955.

This trial tested six varieties replicated six times. There were three levels of nitrogenous manuring (0, 1 and 2 cwt acre "Nitro-Chalk") which were applied to the blocks, each of six adjacent variety plots: each nitrogen treatment was therefore applied to two blocks with only twofold replication. This trial was very precise, the S.E. per variety plot being only 2.95 per cent. The S.E. per fertilizer plot, was, however, 7.16 per cent, reflecting the greater soil variation on the larger plots. This type of trial should be regarded principally as a variety trial, and the lack of precision in determining the less important nitrogen effect is immaterial. It will also show whether the varieties respond differently to nitrogen.

Considering firstly the "main effect" of the varieties (column 1), it will be seen that the two varieties (X and Y), although slightly outyielding the control U, have not done so significantly. V, W and Z have, however, all given significantly lower yields than the control.

Table 3

Crop: Spring Barley Year: 1955

Variety	Mean Yield of Grain at 85% Moisture as % control (1)	Yield of varieties expressed as % mean yield of control N_1 (2)	N_2 (3)	N_3 (4)
U	100 (32.42 cwt/acre)	95	101	105
V	93	87	96	97
W	88	80	90	94
X	101	94	103	105
Y	102	94	105	106
Z	87	83	85	90
S.E.	1.14*		1.98*	
Sig. Diff.	3.42		5.94	
Mean yield at 85 per cent moisture (cwt/acre)		28.7	31.3	32.3

S.E. as percentage mean plot yield: ± 0.91 cwt/acre = 2.95 per cent
Variety × nitrogen interaction: not significant

The "main effect" of nitrogen is given by the mean yields 28.7, 31.3 and 32.3; the first cwt of "Nitro-Chalk" gave 2.6 cwt extra grain and the second cwt produced a further 1 cwt of grain. Although these increases were not significant, however, the extra yield obtained is quite a typical nitrogen response for spring barley. Their non-significance is a consequence of lack of replication, rather than the non-existence of the response. The limitation of this type of design, if it is considered purely as a nitrogen trial, lies in the fact that in this particular trial each cwt of "Nitro-Chalk" would have had to produce a grain response of 13.4 cwt to attain significance.

Such a yield increase would be most exceptional. For a less accurate trial, a still larger nitrogen response would, of course, be necessary. Clearly, it must be most unusual for these trials to give significant nitrogen responses. Since, however, many similar trials are carried out each year, useful information on the effect of nitrogen may be obtained by considering the results of several trials jointly.

Comparisons between varieties may be made *at each nitrogen level* (i.e., in any one of columns 2, 3 or 4) by the S.E. 1.98 and the significant

*S.E. of variety mean $= \frac{0.91}{\sqrt{6}} = \frac{0.91}{2.45} = 0.37$. As a percentage $\frac{0.37}{32.42} \times 100 = 1.14$

S.E. of variety mean at each N level $= \frac{0.91}{\sqrt{2}} = \frac{0.91}{1.41} = 0.64$.

As a percentage $\frac{0.64}{32.42} \times 100 = 1.98$

difference 5.94 (3×1.98) calculated from it; it is not, however, permissible to compare say UN_1 (95) with UN_2 (101) by this means, since this involves a less precisely determined nitrogen comparison.

In this example, variety $\times$ nitrogen interactions were not significant. This is determined in the statistical analysis (the technique is not discussed here) and unless interactions are significant as a whole it is not permissible to pick out individual interactions which may look significant. Had significant interactions existed in this trial, the individual values could be tabulated and tested against the significant difference 5.94.

* * *

Statistical techniques offer the adviser a method of deciding from the results of an experiment whether it is likely to be reliable, and whether the differences obtained are large enough to be important. They cannot help him to decide if the trial was carried out under conditions which make its results inapplicable to his circumstances, nor can they tell him if natural hazards, such as weather, have so affected the trial that its results become of limited value. But they are indispensable nowadays to the solution of those farming problems of which it could be said that: "It happens to be one of those subjects which can never be determined by reasoning, opinions or bold assertions; fair experiments only can resolve it; and whatever may be the results of such experiments, it may be justly concluded, they will be the same in similar soils, climates and situations"[2].

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Reviews and Abstracts

Early Weaning of Calves

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THE PROBLEM, in Britain, of the economical rearing of herd replacements arises from the fact that most of our milk is sold for direct consumption at a price which precludes its use as a feed for calves, except in very limited amounts. As a result, and in direct contrast to the situation in other dairying countries, such as New Zealand, Holland and Denmark, where cheap liquid skimmed milk is readily available as a by-product from the butter industry, profitable calf rearing depends on the use of some form of synthetic milk substitute.

Milk Substitutes

The term "substitute" is often used loosely, and I shall therefore define it, for the purposes of this article, as a substance which is intended to be re-constituted with water and fed in the liquid state to calves. Meals which are to be fed dry are not milk substitutes, as will be apparent from discussions later in the text.

In recent years considerable advances have been made in the study of calf nutrition, particularly in America, yet our knowledge as to what constitutes a satisfactory substitute for whole milk is still incomplete. A calf fed a liquid diet is considered to behave as a monogastric animal (by virtue of the action of the oesophageal groove which effectively allows liquids to by-pass the rumen and reticulum [43]), but there is evidence that its requirements, particularly in respect of carbohydrate, are somewhat critical. As early as 1918, Shaw and co-workers [44] noted that when 40 g starch were suspended in whole milk, and fed to calves, only one-fifth was digested during the first week of life, and not until the calves were between three and four weeks' old did they begin to utilize over 90 per cent of the starch ingested. The experimental technique took no account of starch lost by fermentative action of bacteria, and it is probable that the amounts actually utilized were very much less than the figures showed. In a comparison of lactose, glucose and maize syrup as carbohydrate sources in a synthetic milk for young calves, Flipse *et al.* [15] obtained liveweight gains over a 31-day period of 18.7, 9.3 and 8.7 lb for each of the carbohydrates respectively. In a further trial [16], when starch alone, starch plus lactose and maize syrup plus lactose were tested, weight gains for the first 31 days of life were 14.0, 24.6 and 28.3 lb respectively; diarrhoea being much more common in the starch and starch plus lactose groups. Flipse *et al.* [16] suggested that

the failure of the young calf to digest starch was due to "either (*a*) the inherent weakness of pancreatic amylase with the result that the digestion of starch must await the development of starch splitting micro-organisms in the rumen, or (*b*) the amylolytic activity of pancreatic juices is not developed at birth and fails to become efficient until several weeks after birth."

More recently, Larsen *et al.* [21] fed diets containing either glucose, maltose, starch or maize directly into the abomasum of nine-month-old calves. They found that although glucose and maltose were readily digested, there was very little breakdown of the starch or of the carbohydrate of maize. It would appear that amylolytic activity of the pancreas is still only poorly developed at nine months. Poor results from inclusion of large quantities of starch in milk substitutes for calves have also been reported by other workers [27, 32 and 45]. The ruminant secretes no amylase in its saliva [47]. Moreover, in a natural environment it has no need of amylase, for herbage contains insignificant amounts of starch which in any case would be fermented in the rumen before reaching the abomasum. It is interesting to record that in young pigs the amylase, sucrase and maltase activity of pancreatic juice was nil at birth and then increased gradually to a maximum between three and four weeks for sucrase and maltase, whilst amylase activity continued to increase until the pigs were eight weeks old. Conversely, lactase activity was high at birth and for the first three weeks of life [4 and 20]. Data of this nature on calves are urgently required and would help to put the formulation of milk substitutes on a much sounder footing. It should be stressed, too, that poor digestion of starch does not only mean poor utilization; equally important is the knowledge that undigested starch forms a substrate for bacteria resident in the large bowel, and the subsequent multiplication and fermentative activity of these organisms is the immediate precursor of scour [8].

On the evidence available it seems that starch—which is by far the cheapest and most commonly used source of energy in livestock feeds—is unsatisfactory for incorporating in liquid diets for calves. Fats, whether of animal or vegetable origin—with the exception of butterfat—are equally unsatisfactory for use in liquid diets unless previously emulsified and homogenized [19]. The latter procedure obviously is outside the resources of the average farm.

It seems that the only source of energy that can satisfactorily be incorporated in a synthetic liquid diet for the very young calf is lactose, and to a lesser extent glucose. Thus milk substitutes, at least for feeding to calves under a month old, must be based on by-products of the milk manufacturing industries (the cheapest source of lactose). Dried skimmed milk and dried buttermilk today cost £90 or more per ton. Dried whey is slightly cheaper at about £70 per ton, but its high acidity limits its usefulness in other than small amounts. Glucose is even more expensive. Milk substitutes, although undoubtedly cheaper than whole milk, are much more expensive than the majority of animal feedingstuffs.

Moreover, the limitations on cheap sources of carbohydrate—inherent in liquid feeding, and consequent dependence on gastric digestion in the abomasum—preclude any major economies being made in the future, unless the cost of milk by-products should fall, when, presumably, whole milk would be cheaper too. The only possible line of approach would be to devise a type of gruel that did not cause the oesophageal groove to function but would pass into the rumen to be exposed to bacterial fermentation—but this is to anticipate my main thesis.

There are other disadvantages of using milk substitutes. Warm water is needed and care must be taken to feed at the correct temperature and not to overfeed. Feeding pails must be washed and sterilized, and there is a considerable call on skilled labour. Weaning the calf very early on to dry meal, hay and water would appear to solve most of these difficulties since:

1. Solid food passes into the rumen, where it is fermented by microorganisms, thus simple and inexpensive foods can form the entire diet of the calf within a few weeks of birth;
2. Once the calf is weaned very little labour is required; and
3. The consequences of overfeeding, and the likelihood of scours developing are less than from liquid feeding.

The aim of this technique is not the replacement of whole milk, but the early development of the digestive system of the calf so that it can deal with solid foods. The critical factor to be investigated is the onset of efficient rumen function in the young calf. How soon, in fact, can the young ruminant be treated as an adult ruminant?

Rumen Development

There is very little information concerning the rate of development of the rumen. Benzie (personal communication) has recorded rumen movements in the one-week-old calf, and it is known that the rumen increases in size when solid food, particularly roughage, is fed [7]. New Zealand workers reported the presence of a functional rumen, qualitatively similar to that of an adult, in a 21-day-old lamb on pasture [2]. Armstrong, Preston and Armstrong [3] found that 10-week-old calves digested 75 per cent of the dry matter and 84 per cent of the cellulose of grass, while Preston, Archibald and Tinkler [41], working with similar animals and the same sample of grass, showed that calves attained this digestive efficiency as early as three weeks old and within a few days of being first offered the grass. On the other hand, Dammers *et al.* [14] noted that calves weaned from milk after 60 days and fed dry calf-starter meal and hay digested 13 per cent less of the fibre, 10 per cent less of the protein and 4 per cent less of the nitrogen-free-extractives of the meal than did adult sheep. This comparison may not, however, be legitimate.

With regard to the microbial population of the rumen, it is known that the association typical of the adult is not attained immediately [24]. Pounden and Hibbs [37] suggested that diets having hay to concentrate ratios of 3:2 more quickly induced the appearance of rumen

micro-organisms, characteristic of the adult ruminant, than did diets with higher proportions of concentrates. However, they were unable to demonstrate growth differences between groups of calves fed the various diets. The preponderance of lactobacilli in the rumen of the young calf [17, 24 and 26] and the likelihood, when carbohydrate-rich foods are fed, of an excessive production of lactic acid with consequent ill effects [18] are factors which might militate against the too early introduction of concentrates into the rumen.

Early Weaning

The concept of early weaning and subsequent dry feeding is not new. Mead, Regan and Bartlett [30], working in America over 30 years ago, take first credit for the formulation of a special meal mixture, popularly termed a "calf starter", to be fed in conjunction with a limited milk feeding plan. Subsequent research in that country was concerned with such questions as the minimum weaning age and amount of milk required, and the most economical type of meal mixture. By 1942, it was considered that the dry "calf starter" method was generally preferred to the use of liquid milk substitutes or gruels [42]. Yet despite this swing to dry feeding in America, the method never became popular in the United Kingdom. Traditional beliefs that the young calf requires a liquid diet at least for the first three months, the difficulty of accustoming calves to eat dry food early, and, until fairly recently, lack of any urgency to utilize labour efficiently—are some of the reasons why farmers in this country preferred to feed milk, milk substitutes and gruels. However, there are signs that the diminishing profitability of farming and the consequent need for greater efficiency in livestock production—accentuated by increasing difficulty and cost of providing labour—are overcoming traditional prejudices and leading to serious consideration of the obvious advantages of early weaning and dry feeding.

Although many factors contribute to the efficacy of early weaning as a means of reducing rearing costs, the following may be considered to be the most important.

AGE OF WEANING AND LEVEL OF MILK FEEDING

In their original proposal in 1924, Mead *et al.* [30] advocated feeding whole milk for 30 days and then gradually reducing the amounts fed, until at 40 days, the calves were receiving only dry meal, hay and water. In later experiments the milk feeding period was reduced still further, until the calves were off milk completely at 30 days of age [5]. This method, which became known as the "New Jersey" system was criticized by Norton and Eaton [33] on the grounds that calves so reared invariably suffered a severe setback at weaning and did not achieve normal weight and size until they were between six and nine months old. These workers suggested that an extended milk feeding period to at least 50 days produced more consistent results. More recently there has been renewed interest in four weeks' weaning, and Converse [12] and Whiting and

Clark [48], have reported growth rates, comparable with accepted norms, for calves taken off milk at 30 days of age.

It is to the rearer's advantage to wean the calf as early as possible for concomitant labour and feeding costs are thereby reduced. But he also wants to be assured that his calves will grow satisfactorily. In view of the variations in environmental conditions governing the results of experiments carried out at different centres, the only valid comparison of the effect of weaning age on subsequent growth is to be found where this variable has been studied in the one experiment. Converse [12], comparing weaning at 90, 60 and 30 days of age, noted that although those calves weaned at 30 days sometimes lagged behind the others for the first month or two after weaning, invariably by six months the different groups were indistinguishable. Similar findings were reported by Alexander [1] who fed 40, 20 or 15 gal milk over the first 12, 6 or 5 weeks of life. In the early stages growth rates were proportional to the amounts of milk fed, but the calves fed only 15 gal grew very rapidly after weaning, and by six months were as heavy as those more liberally fed. Preston [38] fed 13 gal milk either at a fixed amount per day to 23 days of age, or in gradually decreasing quantities until 31 days, and found that although the abruptly weaned calves checked slightly after weaning, the mean daily weight gains to twelve weeks were the same for both groups. In subsequent experiments [40] some calves were successfully weaned on to dry meal as early as two weeks old, but it was found that others were unable to make the adjustment to dry feeding at this age and digestive upsets occurred. These difficulties were rarely encountered when calves were weaned at three weeks.

There is little or no evidence concerning the optimum daily rate of milk feeding. Most investigators advocate feeding milk at the rate of 10 per cent of liveweight, the amounts being reduced gradually in the final week before weaning [5, 12, 13, 30 and 48]. Feeding at the lower level of 7.5 per cent of liveweight was recommended by Alexander [1] and in one trial calves fed at this rate grew faster than others fed at 10 per cent of liveweight. There is a greater risk of scour developing with the higher levels of milk feeding; moreover, it is possible that keeping the calf hungry for milk induces it to eat meal before weaning and thus minimizes the weaning check. For purely economic reasons, low levels of milk feeding are to be preferred, although there is a minimum below which susceptibility to disease increases, particularly in very cold weather. A gradual reduction in the milk allowance just prior to weaning is considered by most authorities to minimize the check at the changeover to dry feeding. While this may be true when animals can be established on the dry feed before the changeover, it is not necessarily the best method for conditions of very early weaning, when it occasionally happens that a calf will not eat dry food as long as milk is being fed. In this case, a gradual reduction in the milk allowance means that the calf steadily loses weight during this period and when, realizing

that no more milk is forthcoming, it begins to eat meal, it is in poorer condition than if the changeover had been made abruptly.

Cunningham and Nelson [13] consider that for successful early weaning milk feeding should be continued in limited amounts until the calf is eating at least $\frac{3}{4}$ lb of meal daily. However, the difficulty they experienced in accustoming the calves to dry meal might have been due to the rather unpalatable mixture which was used. Certainly, such a procedure would be almost impossible when group feeding is practised.

COMPOSITION OF THE DRY MEAL MIXTURE

Although most authorities consider that a dry meal mixture for early weaned calves should contain at least 20 per cent of crude protein [12, 13, 33 and 48], no experiments have been carried out to determine the optimum protein level. Preston [39] reported satisfactory results with a meal mixture having a nutritive ratio of 1:5 (the same as for whole milk) and a protein content of 16 per cent. More research is needed on this point. There appears to be no advantage in animal protein *per se* [33, 42 and 48], presumably because the early onset of rumen function enables the calf to synthesize the essential amino acids and those vitamins like B_{12} and riboflavin associated with animal protein and not supplied in all-vegetable protein diet.

Supplementing the meal mixture with minerals and vitamins A and D is an obvious precaution when milk feeding is discontinued at an early age. The dry stabilized form of the vitamins is to be preferred in view of the possible incidence of muscular dystrophy with diets containing col liver oils [9].

Ingredients most commonly used in dry meal mixtures have been maize, oats, bran, linseed cake, soya bean meal, blood flour, dried skim milk and molasses. Palatability is an important factor in ensuring maximum consumption of meal, particularly in the first few weeks after weaning. Whole or cracked maize was preferred by calves to ground maize [34]. In one trial [28], when calves had free choice of various foodstuffs, the amounts consumed were whole maize 319 lb, maize meal 98 lb, whole oats 96 lb, bruised oats 26 lb, linseed cake 116 lb and bran 55 lb. Self-fed calves offered a mixture of three parts whole maize, one part whole oats and one part linseed cake gained 1.31 lb per day, compared with gains of 1.06 lb per day for calves fed the same mixture in ground form [29]. Berry [6] found that the addition of dried skim milk to meal mixtures resulted in improved weight gains. Preston [39] also reported that the inclusion of 10 per cent dried skimmed milk instead of 10 per cent linseed cake meal resulted in a 20 per cent greater consumption of meal and corresponding higher growth rates. The lactose in dried skim milk was possibly the chief attraction. The advantages of adding sugar (usually as molasses) to meal mixtures have been noted by Norton and Eaton [33], Phillips and Werner [35] and Preston [40]; improved consumptions of meal can be expected with up to 10 per cent molasses in the meal mixture. Higher levels may cause scouring [30].

Since calves prefer whole or coarsely-ground grains it might be thought that cubing or pelleting the meal mixture would be advantageous. Pelleting reduces waste and there is less chance of such food becoming stale. However, there is some evidence that from two to six weeks of age a loose meal is more acceptable [31 and 33]. On the other hand, Lassiter *et al.* [23] found that pellets made to a diameter of $\frac{3}{16}$ in. were consumed in greater amounts than the same mixture unpelleted. More information is needed on this point. In trials at the Rowett Institute [40], Friesian and Ayrshire calves have been eating 5 lb meal daily at eight-weeks-old and consumptions of up to 10 lb daily have been recorded for twelve-week-old calves having unrestricted access to the meal.

Lack of appetite for roughage was considered by Preston [40] to be one reason for digestive upsets in certain calves weaned from milk at two weeks old. Withholding meal for several days until the calves began to eat hay effected an immediate cure. Similar emphasis on good quality roughage for early weaned calves has been commented on by other investigators [5, 13 and 33].

ANTIBIOTICS

Feeding chlorotetracycline (aureomycin) and oxytetracycline (terramycin) to calves during the first twelve weeks of life has been shown to reduce the incidence of scouring and to increase liveweight gains, feed utilization efficiency and appetite [22]. There is some evidence, too, that chlorotetracycline promotes the development in the rumen of the physiological conditions necessary for the efficient utilization of dry meal. In one experiment [25], the calves fed this antibiotic had larger rumens, and the pH of their rumen contents was higher than in comparable control animals. Moreover, the findings of Swanson *et al.* [46] that the response of young calves to chlorotetracycline was less consistent with liberal milk feeding than with substitute diets suggests the probability of specific advantages from antibiotics in early weaning systems.

ENCOURAGING THE CALF TO EAT DRY MEAL

Putting grain into the calf's mouth, rubbing it on the animal's wet muzzle or dusting it into the bottom of the milk pail were reported by Converse [12] to be effective methods of inducing the calf to eat meal early. Another technique was to mix the grain feed with warm water immediately liquid milk feeding was stopped [12]. Similar stratagems were employed in early experiments at this Institute [40], but such practices are time consuming and reliance is now put on absolute hunger by abrupt weaning. Certainly the few calves that fail to eat meal before weaning invariably do so within a very short time after milk is discontinued. Bohstedt [10] found that group feeding led to "competition" around the feed trough and thereby induced greater consumptions of meal. Similar findings have been communicated to me by farmers who have tried early weaning; they consider that when calves are run in small groups, one teaches the other to eat. Feeding equipment and the

design of calf pens are also important when early weaning systems are contemplated. It has been observed [40] that calves in individual pens learn more quickly to eat dry food from buckets than from troughs, probably because they associate the former with milk. Providing water in a bucket adjacent to the meal also improves meal consumption as the young calf alternates frequently between eating and drinking. Access to litter did not affect the age when calves began to eat meal [39].

Converse [12] fed warm water from weaning until the calf was six months old and claimed that this stimulated consumption of hay. However, the wisdom of such a practice is doubtful in view of the incurred labour cost. In exceptionally cold weather warm water fed for a week before and after weaning may help to start the calves on dry meal, but the procedure should not otherwise be necessary.

RUMEN INOCULATIONS

Although it has been established that putting pieces of cud from older animals in the mouths of young calves promotes the development of a microbial pattern typical of that in the adult ruminant [36], calves so treated have not been more thrifty nor made greater weight gains. Bryant and Small [11] reported that such inoculations hastened the development of rumen protozoa but not of typical bacteria, except when calves were isolated very carefully. As the calves in these experiments [11 and 36] were generally fed on milk until seven weeks and thus had time to acquire the necessary organisms by natural means, it might be thought that there would be more likelihood of a response when calves are made to depend on dry food from three weeks of age. However, preliminary results of an experiment still in progress [40], in which three-weeks' weaned calves were inoculated at weekly intervals with rumen organisms from an adult ruminant, has not substantiated this belief. It seems that with normal management, bacteria find their way into the rumen even within three weeks of birth.

DIGESTIVE DISTURBANCES

There are few reports of digestive upsets resulting from the early introduction of dry meal into the diet of the calf. Bloat and indigestion in early weaned calves have been noticed by Preston [40]. The disturbances were mainly associated with too early weaning (at two-weeks-old), or with lack of appetite for hay. The reasons for such disturbances are not known. It is possible that weaning calves at two-weeks-old induces them to eat fairly large quantities of meal at a time when there are insufficient of the desired types of bacteria in the rumen to utilize the meal efficiently. Consequently, the lactic acid-producing bacteria, which are usually the first to become established [17], would multiply rapidly and produce large quantities of lactic acid. The ill effects of excess acidity have been demonstrated in sheep by Hungate *et al.* [18], and it is feasible that the same condition would obtain in calves. This seems to have been the sequence of events with one particular calf [40] which

was eating over 1 lb of meal daily at the age of one week and subsequently showed signs of acute indigestion. A sample of its rumen contents was found to have a pH of 4.8 and a lactic acid concentration of 0.1 M.

By way of recapitulation, the following may be considered as a guide to the practical application of early weaning. The proposals are based on the results of experiments conducted at the Rowett Institute during the last 18 months and embody the more important points discussed in this review.

Recapitulation of System of Early Weaning in Current Use at the Rowett Institute

1. Colostrum is fed for three days, then whole milk at the rate of 8 per cent of birth weight daily. A proprietary aureomycin supplement (the supplement also contains vitamin B_{12} but this is not essential) is added to the milk in amounts sufficient to provide 50 mg aureomycin daily. Terramycin can also be used. The daily milk allowance is divided equally between two feeds.
2. Hay and water are offered when the calf is a week old.
3. At two weeks the calf is offered the weaning mixture in a bucket; increasing amounts are fed until it is eating 4 to 6 lb daily, depending on rate of growth required.

Composition of Weaning Mixture

1¾ cwt	Flaked maize
1½ cwt	Bruised oats
¾ cwt	Molassine meal
½ cwt	Dried skim milk powder
½ cwt	Decorticated groundnut meal
3 lb salt 3 lb bonemeal 3 lb limestone meal	or 9 lb mineral mixture

Stabilized vitamins A and D sufficient to give 4 million i.u. of vit. A and 1 million i.u. of vit. D per ton of mixture.

1.25 lb proprietary aureomycin supplement (containing 3.6 g aureomycin per lb).

4. Milk feeding is stopped abruptly at three weeks.
5. At twelve weeks the early weaning ration is replaced with a simple mixture e.g., 85 per cent cereals and 15 per cent groundnut meal plus minerals but without antibiotics.

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Animal Breeding

1. **Sire by Herd Interaction in Production Traits in Dairy Cattle.** J. E. Legates, F. J. Verlinden and J. F. Kendrick. *J. Dairy Sci.*, 1956, **39**, 1055.
2. **The Progeny Testing of Dairy Bulls at Different Levels of Production.** I. L. Mason and Alan Robertson. *J. Agric. Sci.*, 1956, **47**, 367.
3. **The Progeny Testing of Dairy Bulls: a comparison of Special Station and Field Results.** Alan Robertson and I. L. Mason. *J. Agric. Sci.*, 1956, **47**, 376.

The rapid spread of A.I. for cattle has brought into prominence the progeny testing of dairy bulls. Generally, the bulls at A.I. centres have been selected on the basis of records by female relatives in well-managed herds, and the problem naturally arises whether the sire which produces daughters with the highest yields in good conditions of feeding and management also produces daughters with the highest yields in poor conditions.

American authors [1] studied the performance of nearly 25,000 daughters (mainly Holsteins and Guernseys) in herds throughout the U.S.A. The British authors [2] used 13,000 records from cattle of the Red Danish breed which had been bred by A.I. in Jutland. The results from both countries agree in showing that particular sires are good, average, or poor for all herds. If, therefore, bulls are chosen on their performance in high-yielding herds, they should also produce the best progeny for the poorer conditions found in commercial herds.

In Denmark, special progeny-testing stations are used to assess the breeding value of bulls used in A.I. Fifteen to twenty heifers from each sire are sent to special farms and milked under carefully regulated conditions. Robertson and Mason [3] have compared the results obtained at these stations with the performance of daughters in the field. They found that for milk yield, the test station results were a very poor guide to the yield of daughters in the field. Bulls with a superiority in the stations of 100 gal had daughters in the field that were only 20 gal above the average. For fat content, the agreement was better in that about half of the difference found in the stations was reflected in the field. The discrepancy is puzzling, but one explanation put forward is that the differences between progeny groups at the stations are increased by non-genetic causes introduced by tying all the daughters of one bull together in the byre.

The conclusion drawn from the study of the Danish results is that the special test stations are of doubtful utility in the progeny-testing of A.I. bulls for milk yield and fat content. The comparison of records from daughters available in the field with their contemporaries was found to be of slightly greater predictive value than the results from test

stations. For these contemporary comparisons, herds at a high average level of production were found to be of especial value, because in them the proportion of genetic variation was much greater than in low-yielding herds.

J.W.B.K.

A Preliminary Report on Growth and Milk Production in Identical and Fraternal Twin Dairy Cattle. P. J. BRUMBY and J. HANCOCK. *N.Z. J. Sci. Tech. A.*, 1956, **38**, II, 184-93

Values for the heritability of milk production estimated by dam-daughter and paternal half-sib comparisons are of the order 20-40 per cent; corresponding estimates using identical twins range from 80-90 per cent. An investigation of this discrepancy using both identical and fraternal twins is reported.

Milk and butterfat production are analysed for ten monozygotic pairs and eleven fraternal pairs, while several growth characteristics (weight and six body measures) are studied using data on fourteen pairs of each type.

Estimates of genetic variability are derived in three ways:

1. from identical twins alone;
2. from fraternal twins alone; and
3. from identical and fraternal twins in conjunction.

The main result is that for milk and butterfat production the three estimates are roughly similar, but for the growth characteristics values derived from identical and fraternal twins in conjunction are invariably lower than the other two estimates. This is taken to indicate that the pre-natal environment has a considerable effect on growth, but that the maternal influence does not extend as far as the products of lactation.

Genetic Differences in Feed Utilization in Dairy Cattle. O. VENGE. *Z. Tierz. Zucht Biol.*, 1956, 67, II, 147-58

In selection for breeding, little attention has been paid to the differences that exist between cows in their ability to utilize food for milk or butter-fat production, selection having been based mainly on high performance, although it is by no means certain that the highest production is the most economical. With the pig, however, efficiency of food utilization has long been an important factor in selection for breeding.

The chief obstacle to developing such studies with cattle has been the absence of food consumption records, but in the Danish progeny-testing scheme for bulls, which began in 1945, such records have been kept, together with details of milk, butter-fat, and age at calving.

This paper's purpose is to demonstrate that genetic differences exist between cows with regard to their ability to utilize feed for production. Estimates of heritability, based on about 3,000 offspring of 100 bulls, were made for several characters, including total butter-fat, total feed units per Kg butter-fat, and amount of production feed units per Kg

butter-fat. Differences in days in milk and in age at calving had considerable influence on the variation between progeny groups. Allowance has been made for these variables in calculating two of these heritabilities, giving a corrected estimate of 40 per cent of observed variation for total butter-fat, and a value of 20 per cent for production feed units per Kg butter-fat. The progeny groups differ significantly even after correction, but 20 per cent can only be regarded as a maximum value for the proportion of the total variation due to genetic causes.

St. C.S.T.

Herbage Seed Production

The present trend towards better and more efficient ley farming presupposes an adequate supply of good quality herbage seeds. To obtain the most suitable strains it is desirable that these seeds should, where possible, be produced in this country. Since 1939, grass seed production has made considerable strides in this country, and in certain areas has become firmly established as a valuable cash crop.

Methods of Sowing

It is generally conceded that, for most grasses, seed production is best when grown in drills. Little critical work has been done in this country on the best drill width for different species, but Evers and Sonneveld [5] recently described a series of seed production trials in Holland which included the investigation of the most suitable row widths for various grasses.

Three strains of ryegrass were sown at row widths ranging from 8 to 20 in. In 1952 the best seed yields of a grazing type ryegrass were obtained from row widths between 8 and 13 in., whilst the best yields of the hay strain came from 16 in. spacing. There was little difference in 1953 between the yields of seed obtained at the different row widths, although the 13 in. spacing consistently gave the best results. A pasture strain of meadow fescue was grown in drills which were spaced at various intervals from 10 to 27 in. apart. The highest seed yield was obtained at the 10 in. spacing with a steady decrease in yield as the row width increased. The difference in cocksfoot seed yield was not very marked at row widths of 16, 20 or 27 in., but the yield was significantly lower at 8 in. Finally, two types of timothy were grown at drill widths of 16, 20 and 27 in. The seed yield of the hay type increased progressively with the drill width, whilst the seed yield of the grazing type was highest at 20 in. In the latter trial there was a tendency to lodge, particularly at the 27 in. width.

In America Buller *et al.* [1] compared the seed yields of cocksfoot

and timothy when grown in either 36 in. rows or in broadcast swards. They confirmed that generally better seed yields were obtained from rows than from broadcast stands. In addition they showed that, when broadcast, a low seed rate at sowing is better than a high rate. Thus cocksfoot, broadcast at 3 lb per acre gave a seed yield of 530 lb per acre compared with a yield of 430 lb per acre from a sward broadcast at 6 lb per acre.

The production of lucerne seed in this country has so far received less attention than other herbage crops, but in a recent paper Zaleski [6] describes experiments on lucerne seed production conducted at the N.I.A.B. in 1951-54. Row width was one of the factors studied, the lucerne being grown in drills of either 24 in. at the rate of 3 lb per acre, or in 6 in. rows at 13 lb per acre. In all the various managements imposed, the seed yield from the wide rows consistently outyielded those from the narrow rows; the percentage difference between the relative yields ranged from 19 to 28 per cent.

Nitrogen Applications

There is little doubt that for good production of herbage seed the fertility of soils must be high. The effect of top dressings with nitrogenous fertilizers does however seem to vary between species. Thus, Evans [2] applied sulphate of ammonia to drills of cocksfoot and timothy at 2, 4, 6 and 8 cwt per acre and compared the seed yield with those of controls. The sulphate of ammonia was applied as a split-dressing, half in mid-September and half in mid-March. The response of cocksfoot to nitrogen was good; in one year the highest seed yield was reached at the 4 cwt level of application, which gave 413 lb more seed than the control, whilst in the next two years there were successive increments in seed yield as the dressings of nitrogen fertilizer were increased to 6 cwt per acre. The nitrogen increased both the number of fertile cocksfoot tillers and also the weight of seed per tiller. It was also apparent that with the ageing of the stand the seed yield showed a greater response to the heavier rates of nitrogen application. In the case of timothy, the application of 4 cwt and above of sulphate of ammonia caused a decrease in the number of fertile tillers, but increased the weight of seed per tiller. These two factors tended to balance out, and in only one year out of three did nitrogen significantly increase the yield of timothy seed.

In two further papers [3 and 4] Evans again showed that nitrogen top dressings (applied at various rates and times) were ineffective in influencing the total yield of seed from timothy. It was concluded that nitrogen tended to stimulate the leaf growth of timothy at the expense of seed-bearing tillers, and the applications of nitrogen (particularly at the high levels) caused the crop to lodge. In America Buller *et al.* [1] also showed that although cocksfoot responded well to nitrogen, the response of timothy was much poorer. Sulphate of ammonia was applied at $2\frac{1}{2}$ or 5 cwt per acre, either in the spring, in the autumn or in a split-dressing, but none of these dressings increased the yield of timothy by

more than 60 lb. With cocksfoot, however, the best nitrogen treatment (5 cwt of sulphate of ammonia applied in the autumn) produced 340 lb more seed than the unfertilized control.

The work of Buller *et al.* suggested that, for cocksfoot seed production, autumn dressings of nitrogen were more effective than spring dressings. In contrast to this, Evans [3] found that a single dressing of 4 cwt of sulphate of ammonia, applied in March, increased the seed yield of cocksfoot by approximately 400 lb per acre, and was more effective than the same quantity applied in September. Dividing the nitrogen equally between autumn and spring resulted in a smaller seed yield than the spring application, and a larger seed yield than the autumn application of nitrogen. Splitting the spring dressing into two had no advantage over a single application in March. His previous work indicating that nitrogen increased both the number of fertile cocksfoot tillers, and the weight of seed per tiller, was confirmed.

Finally Evans [3] showed that 4 cwt of sulphate of ammonia gave a considerable increase in the seed yield of S.23 ryegrass, but it did not appear to matter whether this was applied in the spring as a single or double dressing, or in the autumn, or split between autumn and spring. As in cocksfoot, tiller numbers and seed per tiller were also increased.

Management

Many crops of seed are never grazed, but current research is showing that grazing at certain periods of the year can be taken from seed stands without unduly affecting seed production. The economic advantages of such a system are obvious. Evans (1953) examined the effect of defoliating seed stands of cocksfoot and timothy at various dates in the autumn, winter and spring during three successive seasons. The timothy was cut in either mid-December, mid-February, mid-March, mid-April, or left uncut. Cutting in December or February or March caused a decrease in the weight of seed per tiller, but this was more than offset by an increase in the number of tillers so that there was little change in the *total* seed yield when compared with the uncut control. However, although cutting in April produced the greatest number of fertile tillers, it also resulted in the greatest reduction of seed yield per tiller, and in one season the April defoliation resulted in a significant reduction of the seed yield of timothy. The cocksfoot stands were cut either in mid-August, mid-September, mid-September plus mid-December, mid-March or left uncut. The effect of any cutting treatment (except August) was to increase significantly the number of fertile tillers, whilst all cutting treatments reduced the weight of seed per tiller. The net result over three years was that there was a slight increase in the seed yield of cocksfoot as a result of any cutting treatment when compared with the uncut control. It should be noted that the level of cutting throughout the experiment was lower than that at which stock would usually graze.

Evans [4] followed this work by studying the effect of grazing timothy seed stands with sheep during the winter. The seed production of S.48 timothy, drilled in rows 20 in. apart, and grazed in either mid-December or mid-February was compared with an ungrazed control during two harvest years. In the third harvest year the grazing managements were imposed in mid-January and mid-March. The seed yield of timothy in the following summer was only slightly reduced by any winter grazing treatment. The biggest decrease was caused by the March grazing in the third harvest year when the grazed plots yielded 274 lb of seed per acre compared with 318 lb from the ungrazed plots. It should be noted that the winter grazing was accomplished rapidly (i.e., 3-4 days on each plot). The herbage produced in the winter appeared to be of high quality, the application of 1 to 2 cwt of sulphate of ammonia in the autumn producing about 1,000 lb of dry matter per acre for winter grazing. This out-of-season keep can be grazed between December and February without reducing the seed yield and obviously adds to the value of the crop. It is emphasized that this grazing should be as rapid as possible; prolonged stocking, which resulted in the grazing of any regrowth, would undoubtedly reduce the plant's reserves and would also reduce seed yields.

Finally, the pre-management of lucerne for seed production has been investigated by Zaleski [6]. In France, the common practice is to take seed from lucerne which has been cut in May for fodder. Zaleski found that, in England, cutting lucerne in either April or May resulted in a reduction of the seed yield when compared with lucerne which was not cut prior to harvest. This pre-cutting did not check the second growth, but delayed the time of flowering, ripening of seed and time of harvest. Because of unsuitable weather conditions this late harvest resulted in the sprouting of seed and reduced both the yield and germination capacity.

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H.K.B.

Poultry Husbandry

The increasing popularity of fat in poultry rations, particularly in connection with fast-growing birds reared for the table, was referred to in a previous issue of this REVIEW (No. 33, p. 129). Some of the results recorded with the use of fat have, however, been contradictory. An explanation of these conflicting views is given in a recent paper on "Fat in Poultry Nutrition" by A. L. DAVIDSON (*J. Sci. Food and Agric.*, 1956, **7**, 240-4) which indicates that, if certain conditions are fulfilled, fat may be a useful addition to the chicks' diet in promoting rapid growth. Davidson points out that the reason for the divergence of recorded results in the past would seem to depend on whether or not a proper balance had been maintained between energy and protein. He goes on to state that it is essential to establish the proportion of total digestible nutrients which should be present as protein to secure maximum gains in growth. Employing rations with such optimum ratios, fat could then be used for improved growth and food conversion rates. Davidson points out that an increase in growth rate cannot be expected to follow the addition of fat to a balanced ration. If an improvement does result then it can be concluded that the original ration was in fact unbalanced.

Seaweed Meal as a Supplement

Dealing with another possible supplement to poultry rations in a paper entitled "The Effect of Feeding different Seaweed Meals on the Mineral and Nitrogen Metabolism of the Laying Hen", C. J. E. HAND and C. TYLER (*J. Sci. Food and Agric.*, 1955, **6**, 743-54) discuss the value of seaweed meals of varying types. The three varieties they employed showed a range of crude protein from 14 to 4 per cent and were fed at levels ranging from 10 to 20 per cent of the basal diet. The seaweed meals had no beneficial effect, and high levels tended to be detrimental. From the view point of the commercial poultry keeper there would seem to be no advantage in adding to a poultry ration seaweed meal of the kinds employed and, although a 10 per cent supplement is unlikely to lead to any depression, no especial advantage will accrue. The authors record that because of the high chloride content of the meal, there was a heavy water consumption by the birds, and, consequently, a high level of excretion of water and chloride. The consequent wet litter would be a disadvantage with deep litter birds.

Fishmeal Variability

Of the long-established poultry foodstuffs one—fishmeal—has for some time been the subject of criticism. Adverse comments on the variability of fishmeal have been made over a period of about two decades, although the continued widespread use of fishmeal as a major source of protein in poultry diets would suggest that deficiencies in quality are not

so very serious or frequent in their incidence. More recently, criticism has been specifically levelled at the apparent occasional depressing effect of fishmeal on hatching rates. This criticism was first advanced in 1954 by Black and his colleagues and since their account another paper has appeared on "Observations on the Occasional Depressing Influence of Fishmeal on the Hatchability of Hen's Eggs" by R. COLES (*J. Agric. Sci.*, 1956, **47**, 354-62). In this account the author suggests that stock fed with fishmeal may show sudden occasional reductions in hatching rates because of some batches of fishmeal being affected by heat-resistant bacterial contamination. This suggestion does not accord with Black's findings, for he recorded *continued* depression over two years; however, from the conclusions reached in a recent paper by Miller, there may be more than one factor involved.

In an account of "The Nutritive Value of Fish Proteins" by D. S. MILLER (*J. Sci. Food and Agric.*, 1956, **7**, 337-43), the author draws attention to the difference in the nutritive value between samples of commercial fishmeal and those prepared in the laboratory. A number of samples of fishmeal prepared in the laboratory were lighter in colour and, on test with rats, had a higher protein utilization than a number of commercial samples. Miller concluded that the heat treatment of the fish protein in the presence of moisture (in the fish) resulted in some degradation and thus loss of nutritive value. The better results with the laboratory samples were ascribed to the avoidance of the Maillard reaction which is said to lead to the formation of complexes not available to the animal—the degree of the reaction being characterized by the increasing brown coloration of the meal. Miller considers the amino acids most affected to be methionine and lysine. It may be that overheating is one of the causes of the depression in hatchability found with feeding some samples of fishmeal, but it should be pointed out that if the essential amino acids are sufficient for eggs to be produced at all, then the amino acid content is generally satisfactory for their hatching. As both Black and Coles reported good egg production it seems unlikely that the destruction of the amino acid content of the fishmeal was responsible for the poor hatching they both recorded. It seems more probable that there is more than one condition in fishmeal which adversely influences hatching rates, and most probably overheating may have an effect on the quality of the meal other than the destruction of certain amino acids.

The Effects of Fish Solubles

An interesting account of another fish by-product—fish solubles—is given in a paper on "Evidence for a Substance in Fish Solubles which enhances Vitamin A Storage in Chick Livers" by R. H. HARMS, A. A. CAMP, B. L. REID, E. L. GRANT, B. G. CREECH and J. R. COUCH (*Poultry Sci.*, 1956, **35**, 285-91). These workers found that the addition of fish solubles to a chick diet increased the vitamin A storage in the livers. The vitamin A present in fish solubles, and determined by chemical

analysis, was very low in biological activity. The factor in the soluble enhancing the storage of vitamin A was found to be in the water-soluble part. These findings would imply that fish solubles would be a useful addition to a chick ration marginal in vitamin A. However, in a paper on "The Influence of Dietary Carotene on the Mortality Pattern of Fowl with some Observations on the Influence of Condensed Fish Solubles" by R. COLES, R. F. GORDON, L. G. CHUBB and F. CUMBER (*J. Sci. Food and Agric.*, 1956, **7**, 692-9), the authors drew attention to the high mortality from Avitaminosis-A among birds when fish solubles were supplied to a ration marginal in vitamin A. The death rate from the birds receiving only the vitamin A deficient diet was not as high as that in the group where the food was supplemented by fish solubles. Furthermore, the solubles did not have any adverse effect when fed with diets having ample vitamin A. It may, therefore, be that liver storage only occurs above a certain level of dietary vitamin A—if the two conclusions are to be correlated. The apparent divergence may relate to the possible opposing influences of the water-soluble part of fish solubles—which appears to promote vitamin A storage—and the residue which may be that part leading to the destruction of vitamin A. This conclusion gains some support from the fact that both Black and Coles found that the presence of fishmeal in the diet led to a decrease of vitamin A in the hatching eggs produced from such a diet. Since fish solubles are by no means consistent in quality it may be that different qualities lead to the differing results recorded by the several workers. The suggestion that the non water-soluble portion may exert an undesirable influence may prove a useful guide for tracing the occasional depressing influence of fishmeal which has already been discussed.

Limestone Grit Versus Flint Grit

From time to time the controversy between the relative merits of limestone and flint grit flares up. For the most part the protagonists have little evidence to support their opposing views. It is therefore of especial interest to learn of the conclusions set out by C. TYLER in his paper on "The Variations in Limestone and Flint Grit Consumptions by Laying Birds" (*J. Sci. Food and Agric.*, 1955, **6**, 696-704). In Tyler's investigation birds were offered limestone grit and flint of 2 mm maximum particle size in separate hoppers. There were marked variations between the amounts of limestone grit consumed by individual birds; this was not observed with flint grit. With limestone grit there was a rhythmic two-day cycle in the level of consumption; again this was not remarked with flint grit. Heaviest consumption of both forms of grit occurred just before dusk, but this did not seem to be related to the absence of food. The more limestone grit consumed by the birds the more was retained—but wastage was large. In the case of flint the intake did not appear to affect retention. There is some suggestion that flint grit is retained in the gizzard for a longer period.

R.C.

Provincial Note

Herbage Seed Production in the East Midland Province

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BEFORE 1939, there was little production of grass seed in the province. A small acreage of Italian ryegrass was grown for seed in the intensive arable areas on contract with the local seed merchants. It has long been a common practice in these areas to take the second cut from one-year leys for seed of broad red clover. A few farmers have maintained local strains of broad red clover by this means for many years, but these never became as well known as those of many other counties or areas of the British Isles. Wild white clover has been taken from old pastures, most notably in Northamptonshire, but on such a limited scale that this strain or ecotype—developed largely from cattle feeding pastures—never became as widely known as the Kentish strain.

The real impetus to herbage seed production came from the war-time demand for ley grasses and clovers when many overseas supplies were cut off. This period roughly coincided with the introduction to the market of the bred strains, better known as the "S" strains. Much care has to be taken in the multiplication of these strains to preserve their qualities of leafiness and persistency. Since both grasses and clovers are highly cross-fertile, fields have to be selected which are free from contaminating species of inferior value and which at the same time are effectively isolated from other sources of cross-pollination. The long tradition of intensive arable cropping in parts of Lincolnshire, and the relative freedom to choose an isolated field, together with the favourable climate of that area made it suitable for the propagation of these strains of herbage plants. Of the total acreage grown under the Field Approval Certification Scheme, approximately one third (8,000-10,000 acres) has been grown annually in the East Midland Province, principally in the counties of Lindsey, Kesteven, Northampton, Nottingham and Leicester. This article refers to the production of the "S" strains, but other strains of grasses and clovers also are now being widely grown for seed in the province.

Isolation and Weed Control

In the arable areas of the province there has not usually been much difficulty in isolating seed crops from neighbouring fields containing other strains of the same species. Since the land has often been cropped for a number of years without leys there is usually a wide choice of species which can be grown. Where farming is more mixed, as in Leicestershire, Northamptonshire and Rutland, the precaution of grazing or mowing adjacent grass at appropriate times has frequently been necessary and the choice of species is more limited.

Blackgrass (*Alopecurus myosuroides*) is often a serious weed of arable land on much of the seed-growing areas of the province. Infestations are likely to be particularly bad on heavy land with a high pH—for example on soils developed over Boulder Clay and Jurassic clays—but all of the heavier soils are suspect. As seeds of Blackgrass are particularly difficult to clean from cocksfoot, fescues and ryegrass, the most careful inspection is necessary before choosing a field for these crops.

Some preliminary trials have been made with TCA, CIPC and other chemicals to control Blackgrass in established stands. Italian ryegrass is also a potential difficulty in crops of these grasses grown on land which has had a one-year hay ley in the previous four or five years, but Yorkshire Fog (*Holcus lanatus*) has not been found so frequently or in such quantity as to cause much difficulty in the selection of fields. Docks (*Rumex* spp.) and thistles (*Cirsium* spp.) have been markedly reduced in arable areas where regular spraying of the cereal crops has been widely practised. It has also been found practicable to spray grass seed crops to control or check these weeds, and the introduction of MCPB offers possibilities of dealing with them in clovers. Trials conducted in the province in 1956, using hormone weed-killers, including MCPB, for the control of docks and thistles in clover seed, have shown that considerable discretion is needed in the choice of chemical, rates and times of spraying, or the yield might be reduced. Other widely distributed weeds which have caused trouble are cranesbills (*Geranium* spp.) in clovers and mayweeds (*Matricaria and Anthemis* spp.) in timothy. Most of the fields proposed for seed production in the province are, however, relatively free from weed infestation.

Establishment and the Use of Cover Crops

Few growers have been prepared to forfeit the chance of profit from a cover crop, although there is evidence that the yields of the slower growing species can be increased substantially by sowing direct. Many cover crops have therefore been tried to discover those which are most suitable for establishing good stands.

CEREALS

The stiff-strawed varieties of spring barley and spring wheat continue to be widely used. Ryegrass, timothy and the red and white clovers have

generally established well when sown in this way. Meadow fescue and cocksfoot have proved more susceptible to the effects of competition by cereal, and, unless recovery is rapid after removal of the cover crop, yields in the first harvest year have been reduced. Various attempts have been made to mitigate the effect of competition on these slow-growing strains. Some success has been achieved by using lower seed rates for the cereal, or by using the normal seed rate but blocking alternate coulters and then drilling the grass seed across the rows of cereals. In a few instances, successful establishment of cocksfoot has been achieved by drilling across the rows of winter wheat through which small pathways have been made by a hoe running in front of the drill coulter. Experience has shown that the hay strains of cocksfoot and fescues are more tolerant of under-sowing in cereals than the pasture strains.

PEAS

Both vining and harvesting peas sown in wide rows have been used extensively as cover crops for establishing cocksfoot, timothy and meadow fescue. Generally the grass seed has been drilled across the pea rows after inter-row cultivations have been carried out, but earlier drilling of the grass seed has given better results, particularly in the drier seasons. Consequently, some growers have drilled the grass seed alongside the pea row and close to it to enable inter-row cultivations to be done at an early stage. The grasses become well established before the peas have made too much growth, and, growing near the base of the pea plant, suffer less competition and smothering effects from the pea haulm when it becomes lodged. Alternatively, the grass seed has been sown at the same time as the peas, and weeds controlled at a later stage by spraying.

MUSTARD AND SUMMER RAPE

These, though not grown extensively, have proved most reliable as cover crops. Competition for light is much reduced, compared with the cereal and pea crops, and the relatively short growing period to harvest has often enabled the undersown plants to make rapid growth in late summer and early autumn. In these crops the grass seed has been sown either in the same drill or across the line of drill after inter-row cultivations for weed control.

SUGAR BEET FOR SEED AND WINTER BEANS

Cocksfoot and timothy have been successfully undersown in both these crops but sometimes weedy stands have resulted.

BRASSICAS FOR SEED

These crops, which are sown in the late summer, have occasionally proved suitable as cover crops when under-sown the following spring.

DIRECT SOWING AFTER AN EARLY CROP

This has been tried with variable success after early potatoes or vining peas. The quicker-growing ryegrasses, particularly Italian ryegrass S.22, have often been established well. With cocksfoot, meadow fescue and timothy, sowing in late June and July has often resulted in failure due to competition from annual weeds, especially chickweed. The slower-growing pasture strains of cocksfoot and fescue have often failed to produce seed in the first harvest year where stands are not well established and tillering by early July.

Seed Rates and Methods of Sowing

The wider spacing of 18-22 in. or more is still preferred for all strains of cocksfoot and timothy using seed rates of 5 lb per acre for cocksfoot, and 4 lb for timothy. Most growers have preferred to keep the same spacing as their sugar beet and other root crops. For meadow fescue and tall fescue a seed rate of 5 lb per acre has also been used for wide drill crops, but where a 14 in. spacing has been adopted to ease harvesting, the seed rate has been increased to 7-8 lb an acre. Ryegrasses in recent years have generally been sown broadcast 12-15 lb per acre, or sometimes in drills of 12-16 in. at 8-10 lb per acre.

Some cocksfoot growers consider that the combination of 5-6 lb per acre of broad red clover and 6-8 lb per acre of cocksfoot is a promising method for mowing in the first year and subsequent seed production. Combinations of ryegrass and white clover have not generally proved satisfactory. Sowing rates for white and wild white clovers have been 4 lb per acre, and for red clovers 8 lb. Some growers are now experimenting by sowing these crops in wider drills at much lower seed rates, as it is thought that the production of seed heads is stimulated by the greater development of individual plants. Wide row crops have usually been sown through a conventional type of cup-feed root drill. The newer type of seeder unit has been used successfully, but awned species of grass seed have sometimes caused blockages. Cocksfoot has been sown successfully through the manure side of a combine drill, blocking every second and third coulter to give a 14-21 in. spacing, and manure distributors have been found satisfactory for broadcasting where the small seeds drill (4 in. spacing) is not available. Experience has emphasized the need for the shallow sowing of timothy, and to a lesser extent, of clovers.

Manuring in the Seeding Year and Management after Establishment

The fertilizers applied to the cover crop have usually proved sufficient for the establishment of the undersown crop, except that undersown clovers are treated with additional phosphate at time of sowing. After harvesting the cover crop nitrogen may be required for some strains of grasses in some seasons to encourage good growth during the autumn.

In the spring of the first harvest year the nitrogen top dressing is usually split, part being given in early March and part late April. The quantities applied are generally 4-6 cwt per acre of sulphate of ammonia or equivalent for cocksfoot, 3-4 cwt for ryegrass and 2-3 cwt for timothy and meadow fescue. Some growers prefer to give these quantities in three applications, the last one being in early May.

Taking hay from stands of S.151 and S.123 red clovers has frequently reduced the yield and delayed ripening beyond the end of September, consequently, most growers now prefer to graze the stands or to take silage before the end of May. Seed growers who have attempted to control the early summer growth of white clover by mowing have generally been less successful than those who have grazed their stands. The importance of bees in securing good pollination of white clover crops has been recognized by the Lincolnshire Seed Growers' Association, who operate a scheme in conjunction with the Lincolnshire Beekeepers' Association for the placing of hives in seed fields.

Harvesting

Throughout the province the harvesting methods adopted in the past have been those designed to secure maximum yields by the safest means. These have proved profitable on farms where a large labour force is employed for growing and harvesting big acreages of other cash crops. Crops of cocksfoot and timothy are usually cut by binders fitted with trays for catching shed seed. The sheaves are usually stooked in fours, and the heads of the stooks are tied to prevent loss of seed from shedding in high winds. After an appropriate time in the field for drying, usually 7-10 days, the stooks may be threshed by travelling combine, or carted to a stack by trailers on which canvas sheets have been placed to catch shed seed. Light showers of rain on timothy crops in stook have often proved to be of advantage in getting a clean threshing of the seed head.

High yielding crops of ryegrass, meadow fescue and tall fescue which usually become lodged some time before harvest, are cut by mowing machine. After a short period of drying in the swath, usually 12-24 hours, many of these crops are placed on tripods, using 20-24 tripods per acre and placing about 6 cwt on each. Tripods are also widely used for red and white clover seed crops. Only light loads of white clover are placed on the tripods, otherwise they become compacted and do not dry quickly. In years of early harvest and settled weather red clovers have been combine harvested from the swath successfully, or occasionally cut by binder and threshed by combine from the stook.

The declining labour force of many farms and the lower prices obtained for many of the strains of grasses and clovers in recent years, have compelled many growers to seek more economical and less laborious methods of harvesting. Consequently, greater use is now being made of

combine harvesting. Apart from possible increased losses of seed due to shedding, the main difficulty in combine harvesting herbage seed crops either direct or from the swath has been that of reducing the high moisture content of the threshed sample quickly and without affecting germination. The installation of various forms of in-sack driers on many farms has done much to overcome this difficulty. Harvesting red fescue S.59 is now done almost exclusively by direct combining. Since the seed of this crop is liable to shatter quickly after ripening, direct combining has not only given a more expeditious form of harvesting, but has sometimes given higher yields of harvested seed. For several years some growers have combined their meadow fescue crops from the swath and occasionally it has been possible to harvest direct. Recently there has been a tendency to sow the crop in narrower rows to prevent excessive lodging and so facilitate direct combining. Broadcast stands of ryegrass have been harvested in a similar way, but the extra leafiness of the plants has often made direct combining a slow and difficult operation. The much higher yield obtained by growing crops of cocksfoot in wide rows has limited the use of the direct combining method because of the abundance of leaf produced when grown in this way. It has been found to be a very slow process since so much green material has to be passed through the drum. With timothy, particularly the S.48 and S.50 strains, the risk of seed shedding has generally been too great to allow the crop to become dead ripe and fit for direct combine harvesting. Moreover, a clean threshing of the heads in one operation has rarely been achieved. Some growers of cocksfoot and timothy have sown their crops in narrower drills of 14 in. so that when cut by a swather the crop is borne on a 10-12 in. stubble which allows quick drying of the swath.

Recent developments in the use of chemical defoliants for the pre-harvest treatment of clover seed crops have done much to make direct combine harvesting practicable. Though this practice is not yet extensive, the results of experiments carried out in the province have shown much promise. In some trials, treated plots were harvested and good yields obtained in crops otherwise written off as a total loss. Sulphuric acid (neat BOV) at 8-20 gal per acre has proved most effective of the chemicals used; pentachlorophenol (PCP) at rates of 4-5 lb in 10-15 gal per acre of tractor vaporizing oil or diesel oil; sodium arsenite, and DNC oil emulsion have been almost as good. Only in exceptionally favourable weather has the direct combine harvesting of clover seed crops been possible without pre-harvest spraying.

Duration of Stands

The wide-drilled crops such as cocksfoot, timothy, meadow fescue and red fescue are left down for three harvest years, rarely longer. Crops of S.100 white and S.184 wild white clovers are taken for seed for two or three years. Crops of S.23, S.101 and S.24 perennial ryegrass were

formerly grown in wide drills and remained for three harvest years, but they aré now sown broadcast and harvested for only two years on arable farms. On farms where numbers of livestock are kept these crops may be left down for three or four harvest years because of their value as grazing during autumn and winter.

Crops of Italian ryegrass S.22, perennial ryegrass S.24, red clovers S.151 and S.123 are taken for seed in the first harvest year only.

Yields

The average yields per acre of cleaned seed and the acreages from which they were obtained for the three harvest years 1953-55 are given in the following table quoted from L.S.G.A. reports:

Table 1

Yields/cwt/acre/Cleaned Seed 1953-55

Species and Strain		1953		1954		1955	
		Average Yield	Acreage	Average Yield	Acreage	Average Yield	Acreage
Ryegrass							
	S.22	4.86	33	7.63	71	10.78	43
	S.24	4.92	7	10.15	15	7.50	87
	S.101	5.15	125	3.37	59	5.79	167
	S.23	4.71	449	4.13	156	5.53	514
Cocksfoot							
	S.37	4.25	553	3.04	463	5.73	266
	S.26	4.32	752	3.51	536	4.49	588
	S.143	4.14	1472	3.90	987	4.31	1286
Timothy							
	S.51	3.49	382	2.17	267	4.50	359
	S.48	3.49	934	2.06	732	3.93	838
	S.50	2.04	193	1.15	127	2.39	129
Meadow fescue							
	S.215	4.24	285	3.40	215	4.96	278
	S.53	2.96	296	2.18	306	2.87	283
Red fescue							
	S.59	1.03	69	4.01	193	3.62	255
White clover							
	S.100	0.87	208	0.33	24	1.90	353
	S.184	0.43	99	0.28	30	1.49	125
Red clover							
	S.123	1.91	220	0.68	25	1.76	262
	S.151	—	—	—	—	1.23	38

Table 2 shows the highest yields obtained from individual crops in 1955 when weather conditions were particularly favourable both for growing and harvesting.

Table 2

Species and Strain		Cleaned Seed
Ryegrass		*cwt/acre*
	S.22	11.97
	S.24	9.98
	S.101	7.25
	S.23	9.14
Cocksfoot		
	S.37	12.47
	S.26	10.00
	S.143	9.77
Timothy		
	S.51	6.50
	S.48	8.55
	S.50	4.38
Fescue		
	S.215	8.01
	S.53	5.80
	S.59	7.81
White clover		
	S.100	4.06
	S.184	2.99
Red clover		
	S.123	5.42
	S.151	2.70

Diseases and Insect Pests

The incidence of choke (*Epichloe typhina*) in cocksfoot has been reported upon in a survey carried out by Seed Crop Inspectors and Plant Pathologists, 1951-53 [1]. This survey showed that the greatest losses due to this disease occurred in older stands of cocksfoot, particularly those in their third and subsequent harvest years. This may well explain the low incidence of the disease in this province, since of two hundred crops inspected in 1956, only 4 per cent were stands of over three years.

Of the many crops of ryegrass grown in the province one crop only of S.24 has been affected by blind seed disease (*Phialia temulenta*).

Damage to timothy seed heads caused by Timothy fly (*Amaurosoma* spp.) has occurred mainly in the S.E. area of Kesteven where the sight of approximately one third of many of the seed heads stripped of their seed before harvest caused much concern amongst growers. The highest infestation of heads reported by Coghill and Gair [2] in their survey of Timothy fly damage in the field, 1948, was 34 per cent. In 1956 an

examination of one crop of timothy in Kesteven showed an infestation of about 50 per cent of heads. This exceptionally high incidence has prompted an investigation by our provincial entomologists on methods of chemical control.

Little damage has been reported on red clover from attacks of the Clover Seed weevil (*Apion* spp.) but some growers have sprayed their crops as a precaution. Poor seed setting of many of the red clover crops in Lincolnshire due to lack of pollination has caused more concern. During the past three years a survey of clover seed yields has been conducted in conjunction with the N.I.A.B. and a study made of some of the causes of poor yields.

Many crops of cocksfoot in Lincolnshire have suffered considerably from frost damage during late January and February. The crops most affected have been those in their second and third winter which have made strong autumn growth. The effect on subsequent seed yield of controlling the amount of leafy autumn growth by winter grazing is being studied.

The Lincolnshire Seed Growers' Association

The Association was formed by a small group of growers, merchants and technical officers in 1944. Its aims were to foster the growing of herbage seeds and to exchange information on the techniques of growing and harvesting. As acreages increased and membership of both merchants and growers expanded, more and more services were required of the Association. In 1947 a full-time secretary was appointed with offices in Lincoln. In 1948 a voluntary scheme for the certification of the seed of those crops certified under the Field Approval Scheme was inaugurated. Each crop on the farm was sampled after threshing or drying; the bags were sealed and labelled stating the grower's and crop number, the species and strain of crop. Five samples were taken, one of which was retained by the grower, the second sent to the approved processor of the seed, the third and fourth to the N.I.A.B. and O.S.T.S. for germination, purity and growing on tests, and the fifth retained by the secretary of the Association for two years. The processed seed was subject to sampling for similar tests by O.S.T.S. and by the N.I.A.B. On attaining the requisite standards the processed seed received a certificate issued by the Association bearing the appropriate numbers of the crop, grower and processor.

In 1953 a fully equipped seed testing laboratory with trained personnel was set up at the Lincoln offices. All tests on the seed from grower members whose crops passed through the scheme have since been made in this laboratory. From the inception of the pilot scheme for seed certification in 1948 until 1956, when the National Scheme for Comprehensive Certification of Herbage Seeds came into being, some 7,300 tons of seed have been certified by the Association. The total membership in May 1956 was 291 growers and 36 merchants.

Conclusion

Herbage seed production has now become an established feature of the cropping on many farms in the East Midland Province. It has enabled farmers to widen their rotation with a cash crop which is restorative of soil structure and fertility. Growing and harvesting of herbage seed crops has fitted in well with existing resources of manpower and equipment, often enabling its greater use over the season. The aim has been to secure the highest yields of quality seed with generous fertilizer applications, good cultural practices and care in harvesting in accordance with good arable farming traditions.

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